A Remote Sensing Survey of Deepwater Port Group on Yangtze River Delta

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***Abstract*—This paper described the survey of Zhoushan and Ningbo deepwater port group by using TM/ETM$^+$, SPOT, ESR-2SAR and NOAA-AVHRR remote sensing data, as well as other general data. TM/ETM$^+$ and SPOT remote sensing images were used to obtain the information about port conditions, shoreline types and storage fields. Images of ERS-2SAR were employed to survey the marine environment factors such as front and internal wave. TM/ETM$^+$, SPOT and NOAA-AVHRR data were utilized to detect the suspended sediments. Based on the surveying results, assessments were made for the deepwater port resources in the study area.**

Keywords: Yangtze River Delta, deepwater port group, port resources, remote sensing

I. INTRODUCTION

In recent years, remote sensing technology has been extensively used in various applications for ocean and coast research. Most remote sensing applications were developed for single goal and purpose. So there are not many reports about comprehensive research on port resource and environment utilizing the remote sensing technology. In this study, remote sensing technology such as TM/ETM+, SPOT, ERS-2SAR and NOAA-AVHRR, along with other routine technologies, were used to study the deepwater resources in Zhoushan-Ningbo area, which is part of the great Yangtze River Delta area. TM/ETM+ and SPOT remote sensing images were used to obtain the information about port conditions, shoreline types and storage fields. Images of ERS-2SAR were employed to survey the marine environment factors such as front and internal wave. TM/ETM+, SPOT and NOAA-AVHRR data were utilized to detect the suspended sediments. Based on the survey results, assessments were made for the deepwater port resources in the study area.

The target study area is the deepwater port between Zhoushan and Ningbo in South-Eastern Zhejiang Province, longitude 121° 20'~122° 40 ' E, latitude 29° 30 ' ~ 30° 45 ' N. Zhoushan-Ningbo deepwater port group located at the central point of the offshore navigation line in China's Southeast Coast, which is also well known as China's "T-shaped" economic structure. It is one of these key port cities located at Yangtze River valley in South-Eastern China, which is famous for its economically well-developed surrounding areas like Shanghai, Zhejiang, and etc. It is the key junction of the north-to-south coastal navigation line in China, and also the mouth of Yangtze River. It is about 13.5 nautical miles south of Shanghai; about 500 nautical miles from Nagasaki in Japan, and Pusan in Korea; about 600 nautical miles from Gaoxiong, Pyongyang, Seoul etc.; about 700 nautical miles from Hong Kong, Kobe, Osaka, Manila, etc. It has formed an equal-distance shipping network with many large ports in Japan, Korea, and other Southeast Asia countries.

II. METHOD

A. Data and materials

The remote sensing data used in this study included TM/ETM$^+$, SPOT, NOAA-AVHRR and ERS-2SAR data as shown in table 1. The topographic map, sea chart, current port situation and planning drawing of the study area were all adopted, which included Zhoushan-Ningbo port group topographic maps (1:100,000), Zhoushan–Ningbo port group sea chart (1:80,000), Ningbo port plan (1:35,000) and Zhoushan port plan (1:100,000) drawing. Also included in the study were some marine hydrology survey data, ocean meteorological data, and the silt survey data of the area.

Table 1 Remote Sensing Data

NAME	TEMPORAL IMAGE/UNIT	RESOLUTION	TIME
TM/ETM$^+$	2	15m (Panchromatic) 30m(Multi spectrum)	Feb 20th, 1997 Mar.15th, 2002
SPOT	1	10m (Panchromatic)	March 27th, 2000
ERS-2SAR	1	12.5m	July 10th, 2000
NOAA-AVHRR	8	1100m	Each quarter one image in 2001 and 2002

B. Technical Method

This investigation took remote sensing technology as the core, combined some routine census data, the technical method used in the study is shown in.Fig.1.

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14. ABSTRACT

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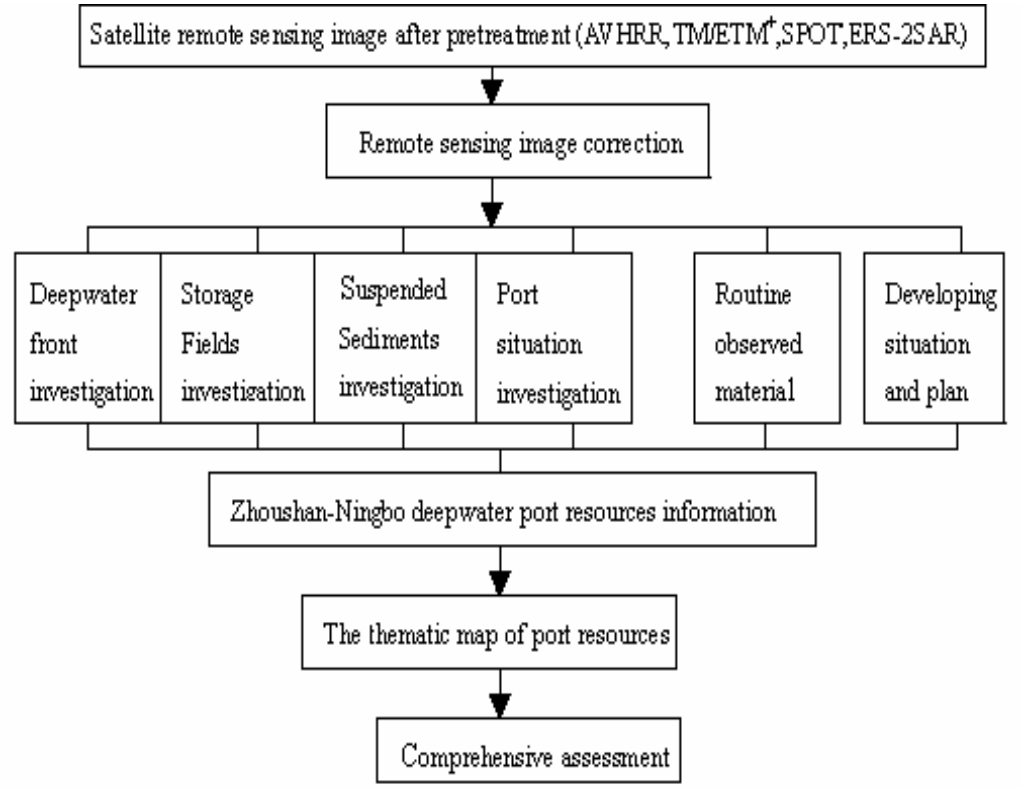

Fig.1Technical method

C. *Data Gathering methods*

1) Deepwater front data

TM image of Feb. 20th, 1997 and ETM$^+$ image of March 15th, 2002 were used to draw the coastline, and the space analytical method was utilized to analyze the water front change between 1997 and 2002. The 1:100,000 topographic maps, 1:80,000 topographical and depth information were used to isolate the deepwater front by analyzing the space using Arcview software. The waterfront was divided into two classes: 10 m and 20m in depth, with waterfront limited from bank 1000m.

2) Storage fields' information

The data from storage fields were gathered in two steps. First, land resources of the main island were analyzed, along with some other routine data. The level land of the area was also analyzed. Second, combined with data from the sea chart and topographic map, land utilization of the main island was analyzed according to satellite images, and the construction position, methods, and difficulty levels were investigated.

3) Harbor suspended sediments information

This study used the remote sensing technology to monitor the suspended sediments in the harbor. 10 scenes were selected from the NOAA-AVHRR, TM/ETM$^+$ images taken during the study, and the one taken on Feb. 20th, 1997 was used. ETM$^+$ image and NOAA-AVHRR were taken annually, and 8 scenes of remote sensing image of the spring, summer, autumn and winter were utilized. Different season harbor remote sensing images were obtained through the satellite images of different time phase. Along with all these information, plus some comparative analysis, we get the distribute state and law of the suspended sediments. Utilize NOAA-AVHRR1~2 and TM/ETM$^+$ 3~4 wave bands, along by adopting the experienced mode, the suspended sediments density information were estimated. Because of the lack of the real data, the actual silt density is not revised.

4) Port environmental condition

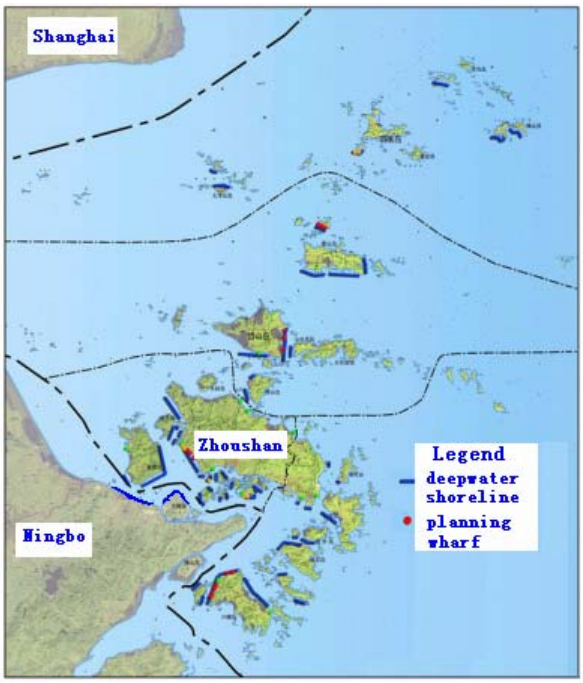

Fig.2The distribution of deepwater shoreline

As one of the ocean environmental key elements, the internal wave is very import to the port construction, anchorage, channel selection, and navigation safety. The ERS-2SAR image was utilized to analyze the internal wave of the study area. From these images, we can get the distribution map and wavelength of the internal wave in this sea area. From the wave energy, we can know the wave destroying strength. Through the brighter strip on SAR images, we can calculate its length.

5) Port current situation

In this investigation, the survey of port current situation adopts the method that remote sensing, topographic map, sea chart combine with port current situation picture, etc. we obtained the distribution situation of the existing port and roughly scale of tonnage. Other information mainly came from the relevant statistical data and the latest materials of websites.

III. COMPREHENSIVE INVESTIGATION

A. Deepwater front resources

TM images of two different time phases were utilized to analyze the coastline change in the study area. The change of the coastline was partially caused by enclosing and cultivating, which lies on the south bank of Hangzhou gulf. Other activities like port building such as Beilun port, Majishan port changed the coastline too. This study adopted the method to use remote sensing and GIS, along with some routine materials. The result indicated there are 849.1km fronts of deepwater in this area. The deepwater front of 10m is 440.2km. The deepwater front of 20m is 408.9km. Because the port construction needs to consider a lot of factors, including channel, anchorage etc., there are only 196.7 km suitable to construct above 10,000t class port. The deepwater front of 10m is 103.9km, and the deepwater front of 20m is 92.8 km.

B. The port storage fields

As a whole, the study area is abundant in the level land and gentle slope resource, approximately 40% of the total area. It can offer enough rear storage fields for future development at the port. There are differences in position, development cost, etc., in every island.

C. Investigation of density of suspended sediments

Through analyzing the sediments image information in the harbor of different time phases, different seasons, we got the sediments distributional state. The content of the sediments is relatively high in this area. The west is low, the east is high, the middle is high, and the north and south both are low. Among them, the Qiqu archipelago where the Yangshan port under construction is one of the supreme districts of the content of sediments. The images of NOAA-AVHRR and TM/ETM^{+} provided the same result. From the seasonal angle, the content of sediments is high in spring and winter, low in summer and autumn. Numerous studies with the routine and historical statistical data and remote sensing image indicated that the total trend is that the sediments content of neap tide is higher than the spring tide.

D. Port environment investigation

This investigation utilizes ERS-2SAR remote sensing technology to survey environmental key element of ocean in this sea area. It mainly focused on the internal wave information and the sharp point of the sea area, which have very great influence on navigation safety of shipping. It is one of the important bases of choosing channel and anchorage. The investigate area have a lot of sharp point and internal wave messages. It is mainly according to such environmental key elements as routine census data and historical materials climate meteorological phenomena, tide and wave of investigating this area, etc. They formed an important base for the comprehensive appraisal regarding the port resources.

E. *Channels investigating*

There are numerous islands in this sea area. There are a lot of fine channel route for all kinds of all ships to sail. By combining the remote sensing image along with the existing routine materials, and take such natural factors as the depth of water, direction of flow, and width of channel, etc. into consideration, we got the distribution states of the route.

F. Anchorages investigating

The numerous islands and crooked coasts form a lot of harbor anchorages. There are more than 10 places for above 10,000 ton class shipping.

G. Port current situations investigating

We can clearly read the quay of most ports from the remote sensing images, and get its distribution map. We can verify it with data from routine survey. At the same time, we can confirm the distribution range and scale of the main port.

IV. COMPREHENSIVE APPRAISALS

From the study, we have got abundant census data. The result indicates that this area possesses fine large-scale deepwater ports terms. There are nearly 200km of deepwater front, which is suitable for the construction of the port. It is rare on the world.

Zhoushan-Ningbo port group holds outstanding natural conditions. It abounds in deep water resources. On the Xiazhi international navigation channel, the fully loaded 150-thousand-tonnage ships can pass freely, the 200-thousand-tonnage ships can save the tide into the port, and 300-thousand-tonnage ships can pass easily by slight modification of the navigation channel. The bank of the port has steep slope, the deep-water coastline is long and straight. The water is deep with smooth flow, so the beach is stable and almost never silted up. The port is naturally sheltered and protected by many islands. There are a lot of entrances and exits to the port, with stable deepwater navigation channels never frozen all year long. Zhoushan-Ningbo Port group enjoys the natural conditions of multiple entrances, large area, deep water, little silt, and sheltered from wind. It is an essential point which connecting China with the world

V. CONCLUSIONS

By using remote sensing technology, the deepwater front, channel water, anchorage, harbor ground base, sediments

distribution, direction of flow, and etc, were analyzed synthetically. Based on the regional port resource data obtained during the study, we found out that Zhoushan-Ningbo deepwater port group possessed the fine large-scale deepwater ports terms, and it is rare in China, and even in the whole world. Study of its long-term sustainable development should be emphasized. The long-term plan of the deepwater port group should be carried out to ensure that.

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